FY2004 IGPP Minigrant Research Project Report

Probing Nature's Particle Accelerators

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Principal Investigators

Project Objectives:

Gamma-ray bursts are one of Nature's most powerful accelerators. The highest energy emission from gamma-ray bursts is key to understanding this phenomenon. This proposal was to analyze data from NASA's highest energy gamma-ray observatory, EGRET, and combine this data with the lower energy gamma-ray observatory from NASA's BATSE detector. By combining this data, we have searched for and found an additional spectral high energy spectral component. This additional component affects the search strategy of LANL's Milagro gamma-ray observatory which is sensitive to even higher energy gamma rays.

Summary of Research Results:

Forty-three gamma ray bursts were selected because of their high flux and fluence in the BATSE detector. Twenty six of these bursts were also detected by the EGRET detector.The EGRET detector recorded the data in shorter time intervals so that 17 of these bursts have multiple spectra yielding a total of 48 spectra. One burst, GRB941017, with 5 spectra showed the clearest evidence of an extra spectral component. This result was published in Nature in August 2003 ("A γ-ray burst with a high-energy spectral component inconsistent with the synchrotron shock model ", González, M. M.; Dingus, B. L.; Kaneko, Y.; Preece, R. D.; Dermer, C. D.; Briggs, M. S., Nature, 424, 749-751, 2003) just prior to the beginning of this proposal. Three other spectra have now been found that also show evidence of an additional component. Each of these spectra is in a different burst and are not as significant as the spectra from GRB941017. Figure 1 shows the three spectra and the probability that the additional component is consistent with a random fluctuation of the background. Given that only 43 spectra were examined these probabilities are sufficiently low to indicate that this additional hard component may be present in other bursts.

If many gamma-ray bursts have such an additional high energy component, Milagro with it's even higher energy threshold may be able to detect more gamma-ray bursts. The origin of this higher energy component is unclear. It may be the signature of ultra high energy cosmic ray nuclei being accelerated by gamma-ray bursts. If so, then detection of even higher energy gamma rays as could be detected by Milagro would be helpful in solving this mystery of the source of ultra high energy cosmic rays. On the other hand this new high energy component may be due to a different type of interaction in gamma ray bursts. The general consensus is that the lower energy component is due to synchrotron emission and so a higher energy component would be due to inverse Compton scattering of these electrons that generate the synchrotron emission. This model also makes a prediction of the Milagro flux that would be detected and also

indicates an even higher flux of gamma rays for Milagro to detect. One such model is shown in Figure 2.

In a few months the SWIFT satellite will launch and a couple of bursts per month are predicted to be in Milagro's field of view. The observation of this higher energy component is making the observations of Milagro even more important. For example, even an upper limit at Milagro's energy of ~1 TeV will constrain models for nearby bursts. This argument was made in a proposal to the Guest Investigator program of SWIFT. This proposal was approved and will bring additional resources to LANL to work on this project.

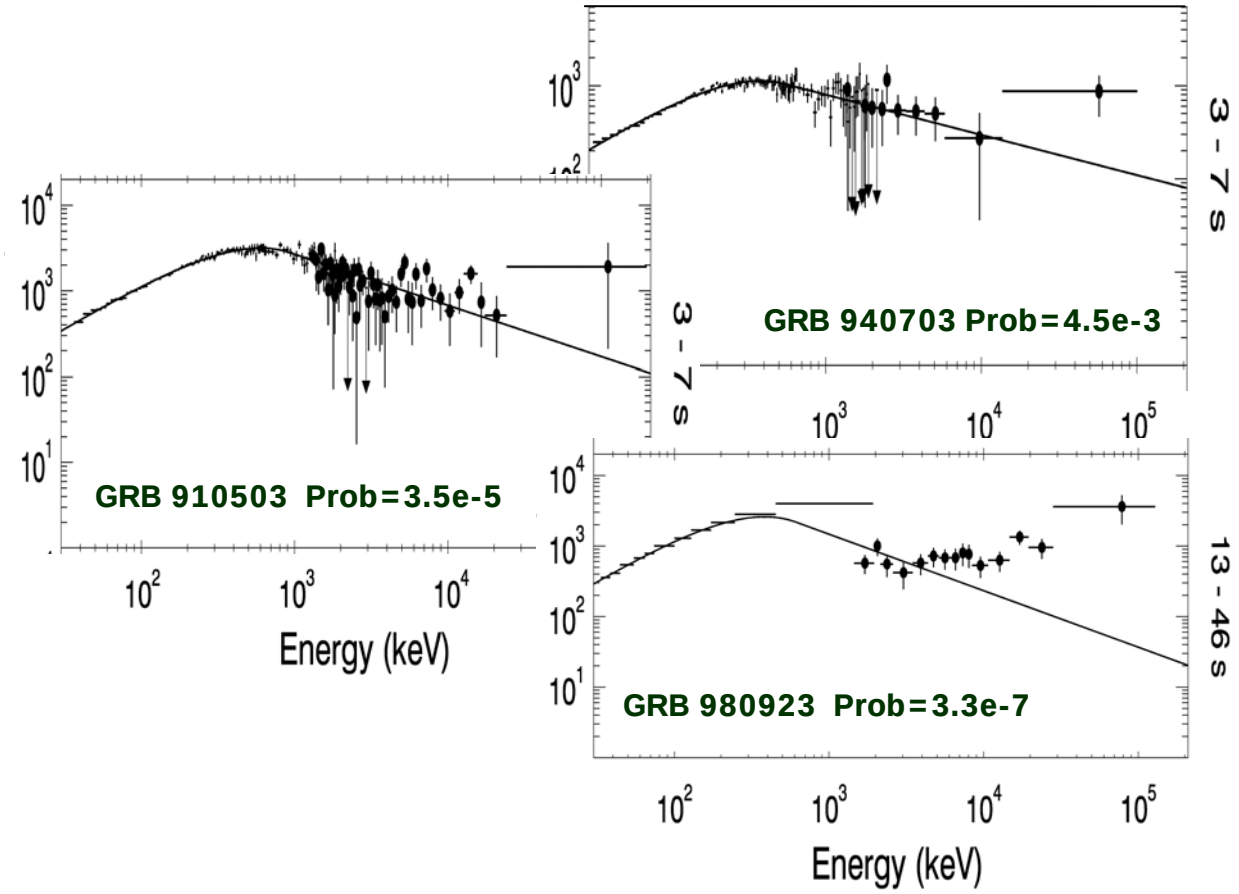

Figure 1: Three spectra from three gamma-ray bursts that are not consistent with an extension of the high energy power law that is shown. The probabilities values are for the chance probability that the addition of an additional high energy component would improve the fit.

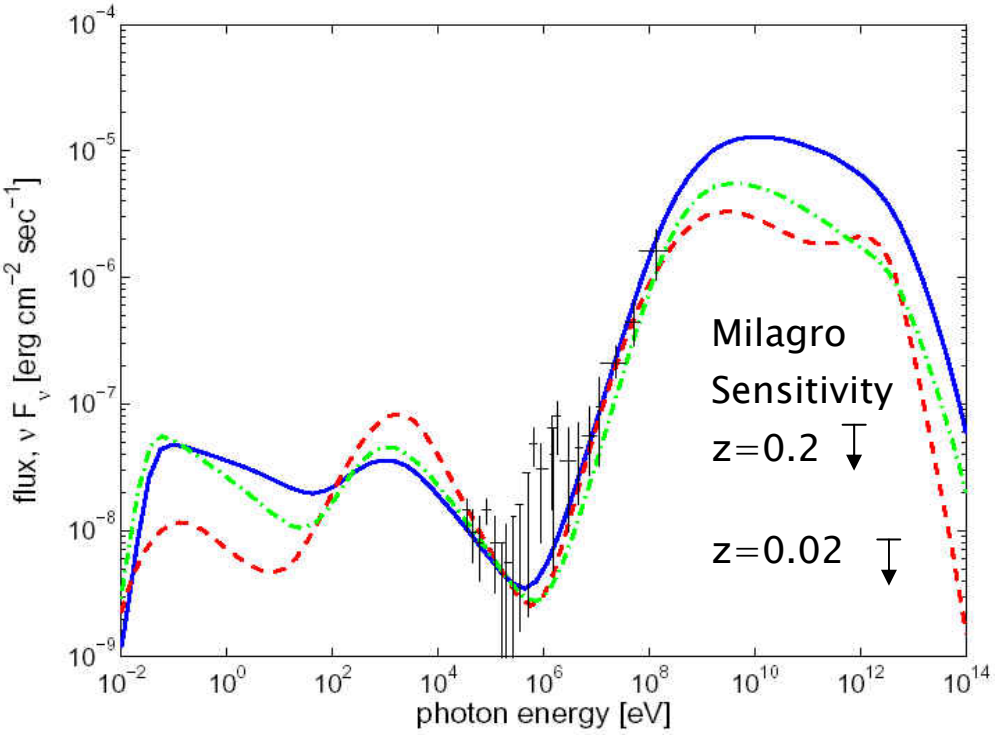

Figure 2: Pe'er & Waxman ApJ 2004 predict that the additional high energy component of GRB941017 is due to Inverse Compton scattering. The three lines are for three different distances to the source. The Milagro sensitivity is also shown indicating if such a burst were within Milagro's field of view and at either of the two redshifts shown, this burst would be easily detected at these high energies.

List of Publications:

"Limits on Very High Energy Emission from Gamma-Ray Bursts with the Milagro Observatory", Atkins, R.; Benbow, W.; Berley, D.; Blaufuss, E.; Bussons, J.; Coyne, D. G.; DeYoung, T.; Dingus, B. L.; Dorfan, D. E.; Ellsworth, R. W.; Fleysher, L.; Fleysher, R.; Gisler, G.; Gonzalez, M. M.; Goodman, J. A.; Haines, T. J.; Hays, E.; Hoffman, C. M.; Kelley, L. A.; McEnery, J. E.; Miller, R. S.; Mincer, A. I.; Morales, M. F.; Nemethy, P.; Noyes, D.; Ryan, J. M.; Samuelson, F. W.; Shoup, A.; Sinnis, G.; Smith, A. J.; Sullivan, G. W.; Williams, D. A.; Westerhoff, S.; Wilson, M. E.; Xu, X.; Yodh, G. B. Astrophysical Journal, Volume 604, Issue 1, pp. L25-L28, 2004.

"Santa Fe Gamma Ray Burst Symposium: 30 Years of Discovery" proceedings, 2004 in press.

Brenda Dingus for the Milagro Collaboration, "Milagro, a TeV Observatory of Gamma-Ray Bursts"

Magda Gonzalez, Brenda Dingus, Yuki Kaneko, Rob Preece, Chuck Dermer, Michael Briggs, "Discovery of a Distinct Higher Energy Spectral Component in GRB941017"

Magda Gonzalez, Brenda Dingus, Yuki Kaneko, Rob Preece, "Spectral Time Evolution for GRBs observed by BATSE and EGRET-TASC"

Kaneko, Y., Hanlon, L.O., Preece, R.D., Gonzalez, M.M., Dingus, B.L., Williams, R., Bennett, K., Winkler, C. "COMPTEL Observation of GRB941017 with Distinct High-Energy Component"

List of Presentations:

Dingus, B. L. for the Milagro Collaboration "The Most Sensitive Survey of the TeV Sky" American Astronomical Society, High Energy Astrophysics Division meeting, New Orleans Sept 2004.

Dingus, B.L., Gonzalez, M.M, Kaneko, Y., Preece, R. "Observations of High Energy Spectral Components in GRBs" to be presented at Heidelberg Gamma Ray Symposium, July 2004. (CANCELLED DUE TO LANL SHUTDOWN).

Graduate Student:

Magda Gonzalez, Ph.D. Dissertator at the University of Wisconsin is nearly finished with her Ph.D. thesis which covers the topics in this proposal. She expects to complete the thesis in the next few months. She spent most of the last year working at LANL with LANL PI Brenda Dingus.

LANL Visit by UW PI:

Francis Halzen visited LANL on October 12, 2004 and gave the LANL Director's Colloquium. He also communicated with LANL PI, Brenda Dingus, and graduate student, Magda Gonzalez and wrote a theory paper based on our analysis of GRB941017. This paper is "GRB 941017: A Case Study of Neutrino Production in Gamma-Ray Bursts" Alvarez-Muñiz, Jaime; Halzen, Francis; Hooper, Dan, Astrophysical Journal 604, Issue 2, pp. L85-L88, 2004.

LANL Facilities:

Both the LANL PI and graduate student were living and working at LANL as well as helping with the operation and analysis of data from the Milagro Gamma Ray Observatory located at LANL TA-53.

Budget Details:

The budget was primarily spent on the graduate student's salary with a small amount of travel and some miscellaneous expenses.

Further Funding:

LANL PI Brenda Dingus successfully proposed to NASA for Guest Investigator funding associated with the SWIFT mission. Her proposal entitled "Milagro Observations of TeV Gamma-Rays Coincident with SWIFT Detected GRBs" was accepted by NASA in June 2004 for $33K.